ECOLOGY AND TIMBER PRODUCTION IN TROPICAL RAINFOREST IN SURINAME*

W. B. J. JONKERS
and P. SCHMIDT

In various places in Amazonia man has tried to convert tropical rainforest into monocultural plantations. In Suriname there are now about 7000 ha of plantations of *Pinus* and about 2000 ha of plantations of other species.

The ecological and economical results of these plantations are not as good as expected. In Suriname the pine plantation were established for pulp and paper production. Some years after the first planting, the paper company involved backed out and the possibility to produce paper got lost. Now it is planned to make telephone poles out of these plantations, but the economical and ecological balances will probably be negative. A positive secondary aspect is that many small Wacapou (*Vouacapoua americana*) trees, which are used now for this purpose, will be saved. Not only in Suriname but in Brazil too the growth of the plantations did not meet the expectations. The discussions on Jari indicate this.

Based upon these experiences we question the feasability of the conversion of neotropical rainforests into plantation forests. Plantation forestry, which is surely well adapted to European or North American conditions, should be only put into use in places, where the original rainforest was destroyed for other reasons, say for mining operations or for farming. If tropical rainforests have to be used silviculturally and economically, other yield systems more adapted to the ecological conditions have to be developed and used. Such a system, called the CELOS-silvicultural system, is the subject of this paper.

The Ecological Conditions of the Forest

If one wants to develop a silvicultural system adapted to the ecological conditions of a site, the best thing to do is to look first at the natural vegetation and to decide which characteristics are essential for the productivity. These characteristics should be incorporated in the silvicultural system.

The research was carried out on two locations in Suriname both about 100 km from Paramaribo (Fig. 1). The Mapane station was established in 1967, the Kabo one in 1978. The soil of both locations is very poor (Table I), with a high percentage of aluminum at the adsorption complex.

According to Köppen, Suriname has a wet tropical climate (Af) with an annual rainfall of 2000-2500 mm per year. Dry periods are from February till March and from August till November. Even in the dryest periods the rainfall will normally amount to 60 mm or more per month.

The forests in question are evergreen seasonal forests (cf. Beard), with a very high number of species (see also Shulz, 1960). Counting only the trees above 5 cm d.b.h. diameter at breast height (1.30 m) on one hectare in Kabo 108 species out of 38 families were found (Schmidt, 1982a). This is very well demonstrated too in Fig. 2, were a small transect of the Mapane forest is given. In this transect of 30 x 10 m 54 trees above 5 cm d.b.h. are found, belonging to 31 species out of 17 families. When small

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Wybrand B. J. Jonkers **holds a M.Sc. from the Agricultural University of Wageningen, the Netherlands (1976). Formerly F.A.O. forestry officer in Malaysia. Since 1981 research fellow (silviculture) for Wageningen University in the LH/UvS01 project. Present address: Agricultural University Wageningen, Department of Silviculture, P.O. Box 324, 6700 AH Wageningen, The Netherlands.**

Pieter Schmidt: **M.Sc. in 1970 in silviculture from the Agricultural University of Wageningen (the Netherlands). Ph.D. (Dr.re.nat.) in 1978 from the Albert-Ludwig University of Fraiburg (Germany). Former research at the University of Freiburg (water consumption of trees) and the Agricultural University Wageningen (tree biology). Since 1980 research fellow (production ecology) and since -1981 projectleader of the joint project of the University of Suriname and the Agricultural University of Wageningen "Human Interference in the Tropical Rainforest Ecosystem", located at the Centre for Agricultural Research CELOS, Paramaribo, Suriname. Present address: Agricultural University Wageningen, Department of Silviculture, P.O. Box 342, 6700 AH Wageningen, the Netherlands.**

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trees, lianas, palms, herbs and epiphytes are included, the number of species is at least 200 per ha.

In the tropical rainforest of Suriname, trees of all sizes occur intensively mixed. The number of trees decreases gradually with increasing diameter. This is also demonstrated clearly in Fig. 2, where a *Sclerolobium* of 1 m diameter and 48 m height is surrounded in the canopy by a few equally big trees, but on the forest floor by numerous small and very small trees. Although little is known about the distribution of the roots, one can safely assume that there is a similar configuration below the ground.

The ecological consequences of these two characteristics are evident. Nearly all niches are occupied and the input of energy and nutrients is almost fully used. The gross primary production is very high, but due to the high amount of phytomass the ratio between the net primary production and the gross primary production is very low. There are many possibilities for mutual aid and the chances for the development of pests are minimal.

The amount of the living phytomass in the Kabo forest is about 480 t/ha: 16 t/ha of leaves, 118 t/ha of branches, 280 t/ha of stems and 65 t/ha of roots (see Fig. 3; Ohler, 1980; Schmidt, 1982). On the floor lies about 34 t/ha coarse and fine litter. An analysis of the nutrients in this system (Fig. 3) shows, that there is an abundant amount of nitrogen, that calcium and potassium are present in fair quantities and phosphorus and magnesium are scarce. The distribution of these nutrients over various compartments of the ecosystem (Fig. 4) stresses the importance of the living phytomass: Between 70 and 90% of the amount of phosphorus, pottassium, calcium and magnesium present in the ecosystem is incorporated in the living phytomass. Nitrogen is the notable exception (see Ohler, 1980; Schmidt, 1982).

In the Mapane forest, the average size of the trees is somewhat smaller and the total amount of phytomass is somewhat less too. The distribution of the nutrients, however, is not essentially different (Schmidt, 1983). The ecological consequence is that the "fertility" of these forests is located in the living phytomass, not in the soil. In a silvicultural system this has to be the same. Because the nutrient capital is stored in the living phytomass, the amount of this living phytomass should always be kept at a high level.

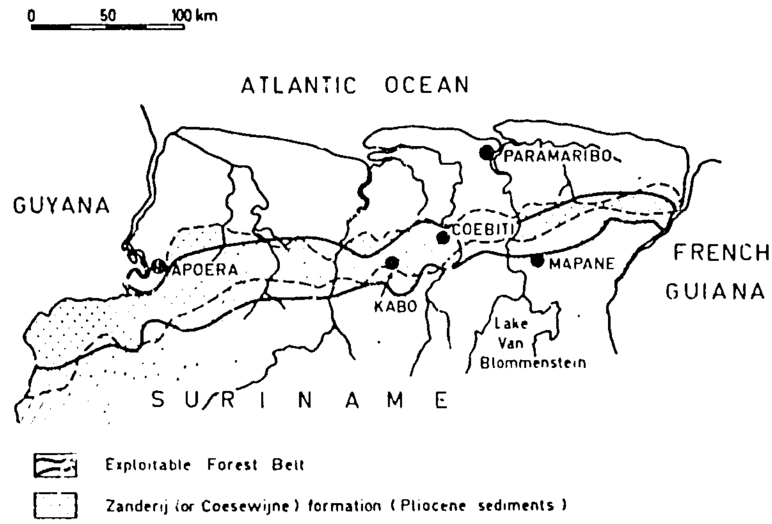

Fig. 1. Map of northern Suriname.

The nutrient cycle in these systems is probably nearly closed. The research of our team into this aspect is not yet in a stage where results can be published. However, it is almost certain that the input of minerals by rain or by the weathering of rocks is limited and that the leaching of minerals is very low as well. This means that the minerals released by the breakdown and decomposition of the litter are recycled, i.e. directly captured again and stored in the living phytomass. The compartment of the ecosystem responsible for this mechanism is the very complicated litter-soil-mycorrhiza-root-symbiosis (see e.g. Jordan and Herrera, 1981). In a silvicultural system this quality of the ecosystem should be kept intact. It is probably more efficient and surely cheaper than artificial fertilizing.

These characteristics work together in the silvigenetical processes of these forests. These processes are centered around the individual tree. As storms or other natural disasters are very uncommon in Suriname, wholesale mortality of a group of trees is a rare phenomenon in the virgin forest. Usually just one tree dies and falls down, thus creating a gap, a chablis. When this happens, light, water and nutrients become available for other trees and seedlings. In the virgin forest the created space is so small as a rule that secondary species and lianas do not get the chance to dominate. Primary species are favored. After the space is totally used, many of these trees can fall back into a state of very slow growth and wait again for a new opportunity. In the CELOS sil-

TABLE I

SOILS IN THE RESEARCH AREAS (0-120 cm DEEP)

Location		Mapane [1]	Kabo [2]
Genesis	—	residual	sedimentary
pH/H_2O	—	3.8 - 4.6	4.2 - 4.8
Org. matter	%	2.03 - 0.28	2.09 - 0.29
CEC at pH7	me/100 gr	7.92 - 2.61	3.36 - 1.26
total bases [3]	me/100 gr	0.73 - 0.12	0.28 - 0.07
Al	me/100 gr	1.99 - 0.87	1.02 - 0.48
Drainage	—	moderate/well	well
USDA-classification	—	orthoxic tropodult typic paludult	ultic haplorthox

1) one oil pit (de Fretes and Poels, typoscript)
2) mean of 118 samples (0-40cm) or 28 samples (40-120 cm) (Boxman, in preparation)
3) K + Ca + Mg

vicultural system, these natural silvigenetical processes are accelerated.

Logging and Silviculture

Logging

When it is decided to use the forest for sustained timber production, the forest is logged first.

A license to harvest the timber above a certain diameter limit (in Suriname 35 cm) is issued to a concessionaire. The licensee has to pay royalty over the logs extracted and is, in practise, free to take whatever he wants and to leave the rest.

The operation starts with the felling. Although the tree feller has to follow the instructions of his employer, he is the one who decides which trees to fell and which to leave. Usually, many good quality timber trees are left standing in the forest, either because the concessionary is not interested in the species at the moment, or because the feller suspects defects in the stem or finds the tree too difficult to fell or as result of mere oversight.

The extraction of the logs should be carried out as soon as possible after felling in order to avoid decay of the timber. In practise the wheeled skidder often arrives long after the first log has been felled. As the skidder operator does not know the location of the logs, he drives around in the forest looking for them. As soon as he spots one, he turns his machine, pushes the log in the right position for extraction if necessary and returns, often with just one log, to the landing on the road side. After unhooking the log, he starts searching for the next one. Usually some good quality felled timber is overlooked by the skidder driver and left to rot in the forest.

In our opinion, such an operation is not efficient. The concessionaire tries to save on management, planning and supervision. The result is that skidding costs are higher than necessary. These extra costs are likely to exceed the savings on management etc. Furthermore, part of the potential production is wasted.

The most likely impression of a visitor, walking on a skid trail shortly after logging, is one of almost complete destruction. This impression may be justified in some (but certainly not all) Dipterocarp forests in S.E. Asia, where 40-100 m³/ha is extracted (see e.g. Fox, 1968, Mattson Marn and Jonkers, 1981). In Suriname, however, where the average yield seldom exceeds 20 m³/ha, the damage is considerable, but the forest is not destroyed.

This is illustrated by the following example (Table II and Figures 5 and 6). Table II is a stand table of an experimental plot in Suriname after a harvest of 42 m³/ha. In spite of the high logging intensity, the stand still contains almost 500 trees per hectare of 10 cm diameter and above. Figures 5 and 6 are maps of the central part of the same plot. Figure 5 shows the skid trails cut stump and the area under fallen trees. Figure 6 shows the crown projections after logging. It is obvious that the damage is concentrated around skid trails and cut stump and that the canopy is intact over approximately 70% of the area. It should be noted however, that the location of the trees to be felled were mapped prior to logging and that this map was used by the skidder operator to locate the logs.

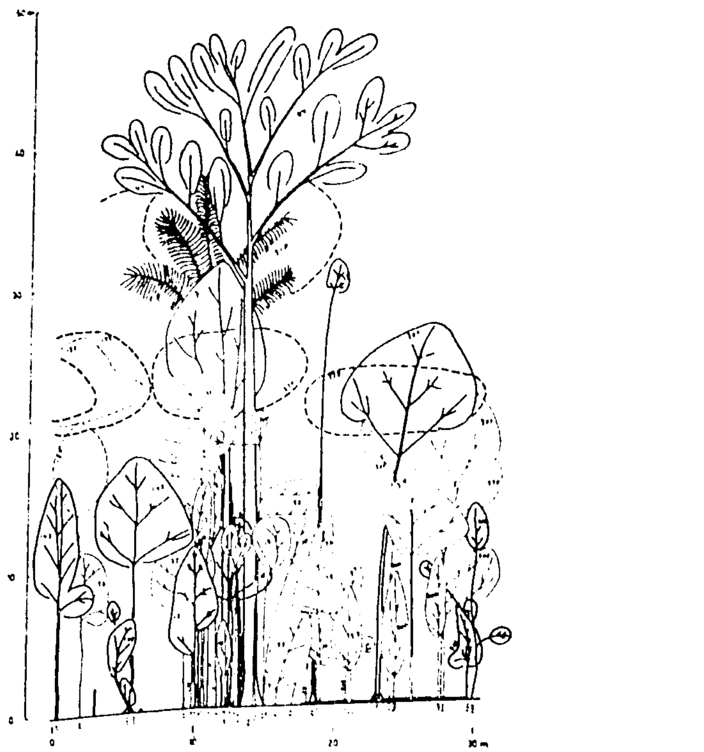

Fig. 2. Forest profile of a small (10 x 30 m) transect of the Mapane forest. Trees above 5 cm d.b.h. only.

TABLE II

DIAMETER CLASS DISTRIBUTION OF COMMERCIAL SPECIES (TAPE MEASUREMENTS) AND ALL SPECIES (CALIPER MEASUREMENTS) IN A SELECTIVELY LOGGED 2.25 HA PLOT. BASAL AREAS IN M²/HA AND NUMBERS OF TREES PER HECTARE

	Number of Trees per ha		Basal Area (m²/ha)	
Diameter Class (cm)	Commercial spp.	All spp.	Commercial spp.	All spp.
10 - 20 cm	45.1	296.4	0.81	4.69
20 - 30 cm	28.0	83.1	1.28	3.58
30 - 40 cm	19.1	52.5	1.76	4.93
40 - 50 cm	12.0	26.2	1.71	4.26
50 - 60 cm	8.0	8.9	1.79	2.04
60 - 70 cm	1.8	3.1	0.56	1.05
70 cm and above	3.1	6.7	2.20	4.36
TOTAL	117.1	476.9	10.11	25.21

A logging technique, ich aims at increasing the efficiency the operation as well as reducing the ging damage is currently being tried experimental scale in Suriname endrison, 1982). Although many hors have emphasized the importance logging damage, such an attempt to uce it is almost unique (other mples: Fox, 1968, Mattson Marn and kers, 1981). Hendrison's experiment usses on the extraction. It is consider- easier to reduce skidder damage than mage caused by falling trees. Further- ore, skidding is by far the most costly rt of the exploitation. The method in- udes among others mapping of terrain aracteristics and trees to be felled, anning of skid trails and directional lling to facilitate skidding. Results from se experiments are not yet ready for blication.

lviculture

The rain forest is a re- wable natural resource. After logging, e residual stand which still includes any individuals of commercial species ee e.g. Table II), keeps growing. nfortunately, this self-renewing process a very slow one.

Since the 1950's, at- mpts have been made in Suriname to in- ease the growth rate of the commercial ecies in logged forest by eliminating mpeting vegetation. The methods tried iginally were based on the Malayan niform System, i.e. virtually all trees ere poison-girdled in order to stimulate e increment of seedlings and saplings commercial species. These species owed a positive response, but secondary ecies and lianas benefitted even more. proved necessary to treat the stand fre- uently in order to keep the growth of e commercial species at an acceptable vel (see Schulz, 1967). Although these rly experiments did not result in an perational system, results were positive ough to justify a continuation of the search.

The basis for the present lvicultural technique was established in 967. The principal aim of the treatment to induce a faster growth of the trees commercial species in the remaining tand, rather than to stimulate the in- rement of seedlings and saplings. This achieved by eliminating competition rom medium-sized and large trees ithout commercial potential and lianas. Furthermore, the treatment has a fer- ilizing effect as the nutrients stored in the killed trees and lianas become available for the remaining vegetation.

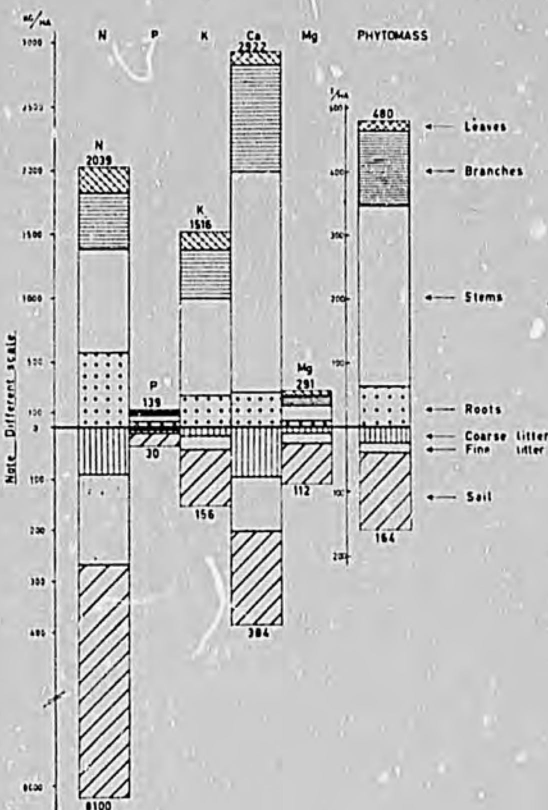

Fig. 3. Phytomass (dry weight, t/ha) and amount of nutrients (kg/ha) in the virgin forest of Kabo (Note: soil analysis by standard methods for agricultural purpose).

The first treatment, which is called refinement, is scheduled one to two years after logging. The instructions are purposely kept simple and can be easily understood by unskilled laborers. The treatment is carried out in four steps (see Fig. 7). First, the tree is identified by a tree spotter. Trees without commercial potential above a certain diameter limit (usually 20 cm) are marked to be eliminated. The tree spotter is accompanied by a laborer who cuts all lianas with a machete (step 2).

These two men are followed by the poison-girdling gang. Marked trees are frill-girdled with a

TABLE III

ESTIMATED EFFECT OF A LIGTH EXPLOITATION (20/Ms**) ON THE PHYTOMASS AND THE NUTRIENT CAPITAL OF THE VIRGIN FOREST AT KABO, GIVEN IN KG/HA AND AS PERCENTAGE OF THE LIVING PHYTOMASS LEAVES + BRANCHES + STEMS + ROOTS)

		Damage by Exploitation			
	Virgin Forest living phytomass	willingly killed and removed i.e. harvest		unwillingly killed not removed	
	kg/ha	kg/ha	%	kg/ha	%
Phytomass	480,000	15,000	3.1	36.000	7.5
N	2,039	43	2.1	213	10.4
P	139	3	1.9	14	9.9
K	1,516	38	2.5	158	10.4
Ca	2,922	92	3.1	341	10.8
Mg	291	7	2.5	30	10.4
Nutrient	6,907	183	2.6	756	10.9

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small axe (step 3). This means, that overlapping cuts are made over the whole circumference of the tree, forming a kind of channel. The cuts should extend just into the sapwood and should make an angle with the vertical of about 45 degrees (see Fig. 8).

After completion of the frill-girdle, arboricide is administered to the tree (step 4). The frill-girdle is filled with arboricide first and then the bark just above the frill is covered with a film of the solution over a height of 10 cm. Up to now a 5% solution of 2, 4, 5-T in diesel oil was used. However, a recent experiment showed that the concentration can be reduced to 2½%.

The effect of the poison-girdling is slow and lasts long. Although the first bare trees are recorded already after a few weeks, it takes a year before 60-70% of the poisoned trees have lost their leaves and several years before this percentage is close to 100%. The branches of such trees fall usually within a few years after it has died. The trunk remains standing as a rule until it is almost completely decayed. This may take a very long time. Even 16 years after the treatment, remnants of many poisoned trees are still standing upright in the regenerated forest. Obviously, the fertilizing effect is long lasting. Furthermore, the number of (commercial) trees killed by falling wood is small.

After treatment, the total basal area should be reduced to approximately 15 m^2/ha, i.e. about half of the pre-felling value. In the example presented in the previous section (Table II and Fig. 6) more than 100 trees per hectare are to be poison-girdled in order to achieve this. A comparison of Figures 6 and 9 provides a visual impression of the changes in the stand as result of the treatment.

Although the treatment worked out well in all experiments, a modification is considered at present. According to the current prescriptions, virtually all trees above 20 cm diameter are to be poison-girdled in very poorly stocked parts of the forest. The experiments carried out in the 1950's show that such a destruction of the canopy results in a secondary vegetation rather than in a good regeneration of commercial species.

The present prescription often have a similar effect in large gaps created by logging. For instance, two medium sized trees in the large gap in the SE corner of Fig. 6 survived exploitation. According to the prescription, they should be poison-girdled (see Fig. 9). However, eliminating them does not serve a purpose as they do not compete with other trees and provide some shade necessary to suppress secondary species. Obviously, poison-girdling should be restricted to the vicinity of the commercial species to be liberated.

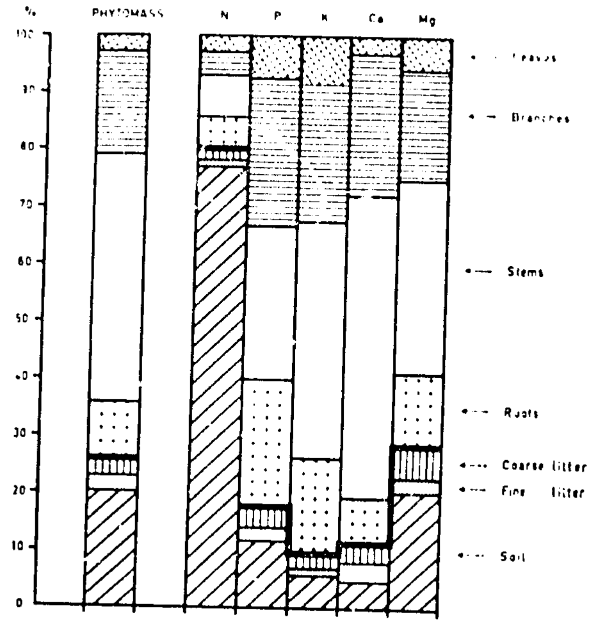

Fig. 4. Distribution of the phytomass and the nutrients over the various compartments in the virgin forest of Kabo (Note: soil analysis by standard methods for agricultural purposes).

After treatment, the diameter increment is greatly increased. Approximately 8 to 10 years later however, the growth rate starts to decline. According to De Graaf (1982) follow-up treatments are necessary after 8 and 16 years in order to keep the diameter

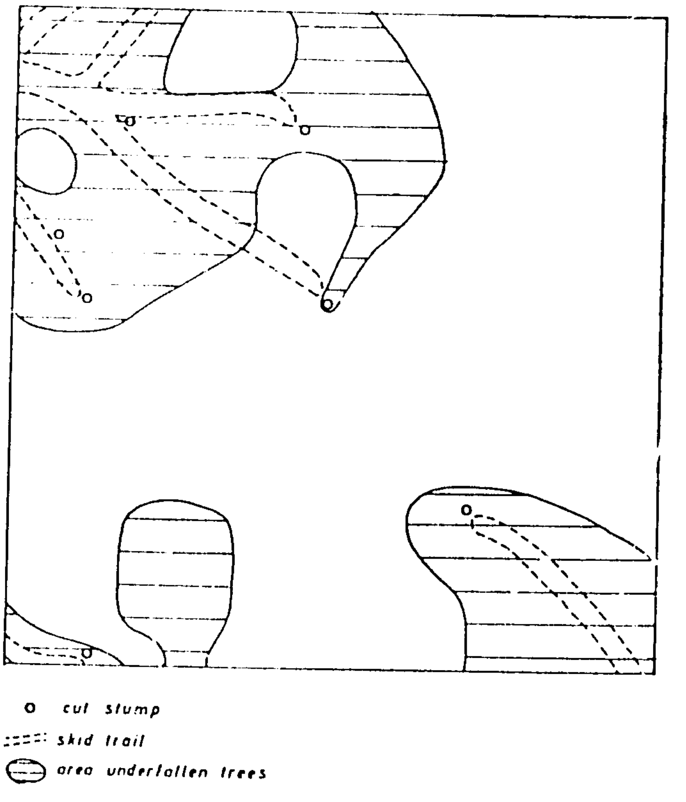

Fig. 5. Cut stumps, skid trails, and the area where the undergrowth has been destroyed by falling trees in an exploited 80 x 80 m plot.

crement at a high level. A second harvest should be possible after 20 years (De Graaf, 1982).

The nature of these follow-up treatments is still a subject of research. De Graaf (1982) suggests poison-girdling treatments down to a basal area of 10 m²/ha (second treatment) and 15 m²/ha (third treatment). Recent results suggest that the second treatment can be delayed by at least two years. This means that the third treatment may not be required at all.

Ecological Aspects

The CELOS silvicultural system interferes in the ecosystem in many ways. Only the ecological effects which are considered the most important for sustained timber production are discussed in this paper.

During the harvest some trees of commercial species are removed, during the subsequent refinement many trees of non-commercial species above a certain diameter level are killed. As a result of these measures but mainly due to the refinement non-commercial species which do not complete their life cycle below the diameter limit of 20 cm are likely to be eliminated completely. As nearly all species which do not produce fruits below this limit are considered commercial, the reduction in number of species is not disturbing. Only a few species run this risk (in Suriname e.g. *Parkia pendula* and *Sclerolobium spp.*).

The diameter distribution of the forest changes too. The number of stems decreases more rapidly with increasing diameter than in a virgin forest and not as gradually. Above the refinement limit all the non-commercial trees are killed and above the felling limit a part of the commercial trees is removed. The remaining forest stands however, is still an intensive mixture of big and small trees (see Fig. 9, for trees above 15 cm d.b.h.).

These changes in species number and in diameter distribution do not seem to damage the forest in such a way, that the ultimate production level will be reduced to an inacceptable height. By harvesting trees, the living phytomass of a forest is reduced. A calculation for the Kabo forest (Table 3; Schmidt, 1983) shows that with the harvested wood 3.1% of the living phytomass and 2.5% of the nutrient capital is removed from the forest. It is expected that the forest can cope with this slight reduction. But a harvest causes more damage. The non-usable parts of the felled trees and the trees damaged and killed by the felling and extraction of the usable trees amount to 7.5% of the living phytomass and to 10.9% of the nutrient capital.

This is about twice the amount of nutrients in the annual

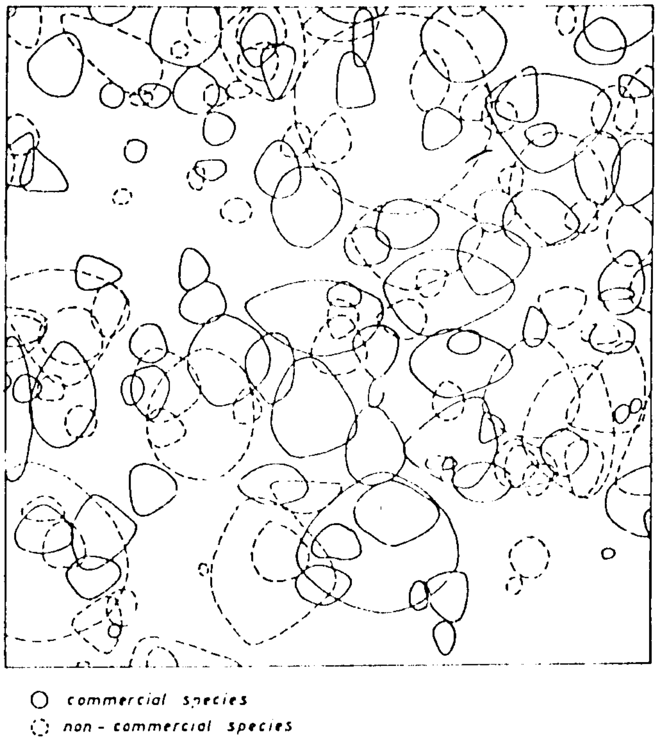

Fig. 6. Grown projections of all trees of 15 cm d.b.h. and above in an exploited 80 x 80 m plot.

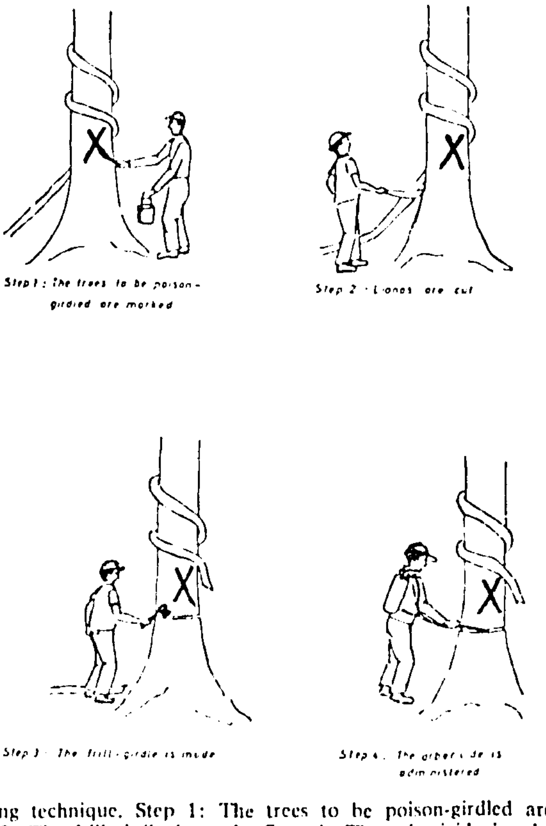

Fig. 7. Poison-girdling technique. Step 1: The trees to be poison-girdled are marked. Step 2: Lianas are cut. Step 3: The frill-girdle is made. Step 4: The arboricide is administered.

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litter fall (leaves, branches, flowers and fruits). It should be noted that these trees and parts of trees are killed, but not removed out of the forest. No nutrients are taken away directly. The nutrient cycle, however, is accelerated. A part of these untimely released nutrients is used as a fertilizer by the remaining trees, but it is possible that not all the nutrients in these extra amounts of litter can be captured again and recycled in the living phytomass. Poels (1983) found a very slight increase of the nutrient contents of a creek after a light exploitation.

A refinement will enhance the fertilizing effect and the danger for leaching. Due to the arboricide treatment 40-50% of the phytomass is killed. In the first few years after treatment leaves of the poisoned trees will fall on the forest floor, followed in the next years by twigs and branches. The stems can remain a decade and more. After a starting gift by the leaves, the fertilizing effect will be spread out over several years, dwindling gradually. The danger of leaching will be greatest in the first one or two years after treatment, when the largest amount of nutrient rich and quickly decomposing phytomass coincides with a recently damaged and not yet restored mycorrhiza-root-complex. The first impressions based upon one year of experiments in a catchment area under a refined forest are that the refinement increases slightly the nutrient concentration in creek water (Poels, 1983).

The results of the research till now into this important aspect of the CELOS silvicultural system can be summarized as follows. No serious indications were found that due to exploitation and refinement significant amounts of nutrients will disappear out of the system. However, the way to the positive statement that the productivity is not endangered, is still a long one. Research into these aspects should be continued, as killing too many trees leads to a reduction in nutrients and productivity. This limits the silviculturist in the prescription of the treatment.

As a matter of course the silvigenetical processes of the forest are altered by a refinement. A refinement is nothing else than playing with these processes, i.e. killing undesirable trees to promote desirable trees. The natural processes are accelerated. But here nature poses a second limitation to the prescriptions of the treatment, as killing too many trees will result in a not very attractive secondary or liana forest.

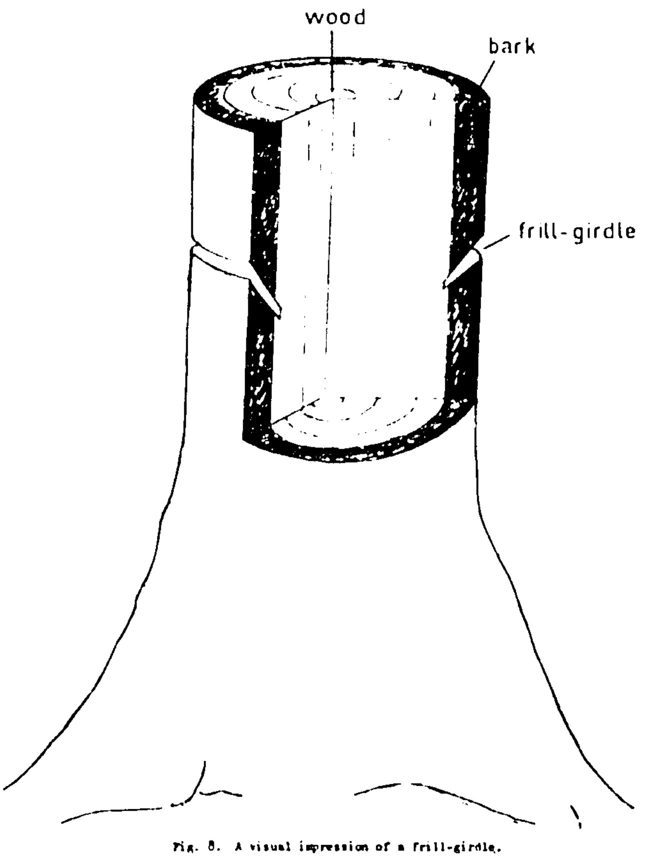

Fig. 8. A visual impression of a frill-girdle.

Economical Aspects

Two important aspects will be discussed now, viz. costs and benefits. Two management options are compared. The first option is doing no treatment after logging. The second one is applying the CELOS silvicultural system described in the section on Silviculture.

No costs are involved when the forest is not treated after logging. Unfortunately, the benefits are almost negligible too. The development of selectively logged forest has been followed since 1967 in various experiments. The annual diameter increment of commercial species (20 cm diameter and more) is about 4 mm/yr and the annual mortality is close to 1.5%. This results in a very slow increase of the harvestable volume.

For example, in the stand presented in Table II, about 37.5% of the commercial trees of harvestable size (50 cm diameter and above) is likely to die within 25 years, i.e. about 4.8 trees per hectare. In the 40-50 cm diameter class about 7.5 trees per hectare survive. These trees are expected to grow into the harvestable size class. So, the net gain of harvestable trees is about 7.5 — 4.8 = 2.7 trees per hectare within 25 years.

When the CELOS silvicultural system is applied, both costs and benefits are higher. The first treatment is probably the most expensive one. Expenditures in two recent experiments, with a treated area of more than 200 hectares were 2.5 mandays/ha of unskilled labor, 0.3 mandays/ha of skilled labor (the tree spotter), 17 liters/ha of 2, 4, 5-T solution plus overhead costs and some minor expenses.

A second treatment has been applied over just two hectares until now. Due to inexperience of the laborers, costs were relatively high. De Graaf (1982) mentions 3.3 mandays/ha and 10-15 liters/ha of arboricide. In a routine treatment, 2 mandays per hectare are likely to be sufficient.

A third treatment has not been applied yet. It is expected to cost about 1 manday per hectare plus a few liters of arboricide.

The CELOS silvicultural system results in a mean annual diameter increment of 9-10 mm/yr and an annual mortality of 2%. De Graaf (1982) estimates the volume of trees which grows into the exploitable size class at 40 m^3/ha in twenty years.

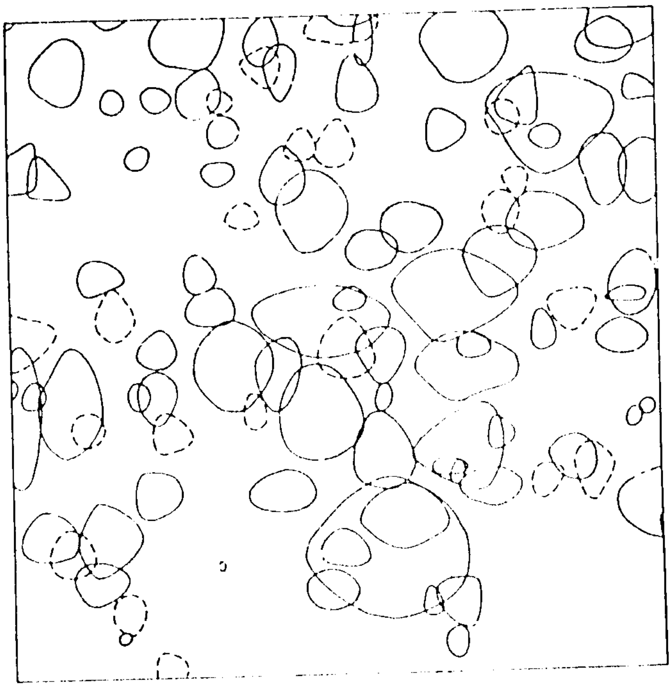

Fig. 9. Crown projections of all trees of 15 cm d.b.h. and above in an exploited 80 x 80 m plot after logging and a refinement with diameter limit 20 cm.

Application of the CELOS system in the stand presented in Table II is expected to have the following results. About 40% of the commercial species of diameter of 50 cm or more are likely to die within 20 years, i.e. about 5.2 trees per hectare. In the 30-40 cm and 40-50 cm diameter classes about 18.7 trees per hectare are likely to survive and reach a diameter of 50 cm or more. So, the net increase in number of harvestable trees is about 13.5 trees per hectare within 20 years, as compared with 2.7 trees per hectare in 25 years when no treatment is applied.

Synthesis

The described silvicultural system for sustained timber production in tropical rainforests consists of two independent parts, an improved harvest technique which aims at a minimally damaged stand after exploitation and silvicultural treatments, which aim at reducing the competition among the trees of the remaining stand in order to concentrate the productivity of the ecosystem on the commercial trees. Many aspects of this system were not yet included in the research program (e. g. fauna, microclimate, autecology). Other aspects are being studied now, but the results are not discussed here (e. g. hydrology, erosion).

However, results up to now of the research into the most critical aspects (e. g. productivity, nutrient capital and nutrient cycling, leaching, species composition and some economical studies) indicate, that the CELOS silvicultural system is economically feasible and ecologically acceptable.

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REFERENCES

De Graaf, N. R., (1982): Sustained timber production in the rain forest of Suriname. In: Wienk, J. F. and H. A. de Wit (eds).: Management of Low Fertility Acid Soils of the American Humid Tropics. IICA, San José, Costa Rica.

Fox, J. E. D., (1968): Logging damage and the influence of climber cutting prior of logging in the lowland dipterocarp in Sabah. Mal For *31*, 326-347.

Hendrison, J., (1982): Harvesting Systems. In: Project LH/UvS 01, Annual Report 1981, CELOS, Paramaribo, Suriname.

Jonkers, W. B. J., (1982): Silviculture. In: Project LH UvS 01, Annual Report 1981. CELOS, Paramaribo, Suriname.

Jordan, C. and R. Herrera, (1981): Tropical rain forests: Are nutrients really critical? Nature and resources, *17* (2), 7-13.

Mattson Marn, H. and W. B. J. Jonkers, (1981): Logging damage in tropical high forest. Forest Department, Kuching, Malaysia.

Ohler, F. M. J., (1980): Phytomass and mineral content in untouched forest. CELOS-rapporten *132*, 1-43.

Poels, R. L. P., (1983): Hydrology. In: Prospect LH/UvS 01, Annual Report 1982. CELOS, Paramaribo, Suriname.

Schmidt, P., (1982): Ecology. In: Project LH UvS 01, Annual Report 1980. CELOS, Paramaribo, Suriname.

Schmidt, P., (1983): Production Ecology. In: Project LH UvS 01, Annual Report 1982. CELOS, Paramaribo, Suriname.

Schulz, J. P., (1960): *Ecological studies on rain forest in northern Suriname*. Van Eeden Fonds, Amsterdam.

Schulz, J. P., (1967): La regeneración natural de la selva mesofítica tropical en Surinam después de su aprovechamiento. CELOS *bulletins Nº* 6, *Landbouwhogeschool*, Wageningen, Nederland.

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